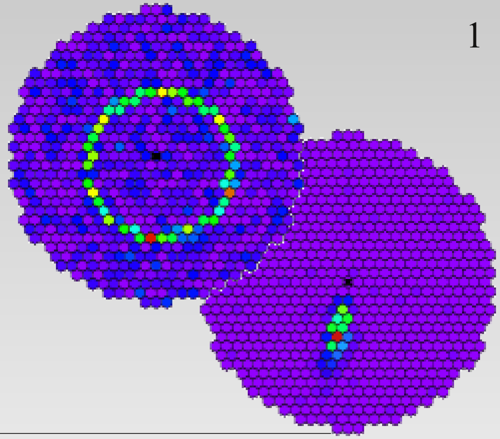
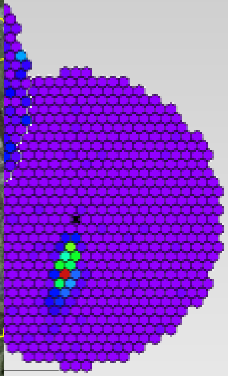


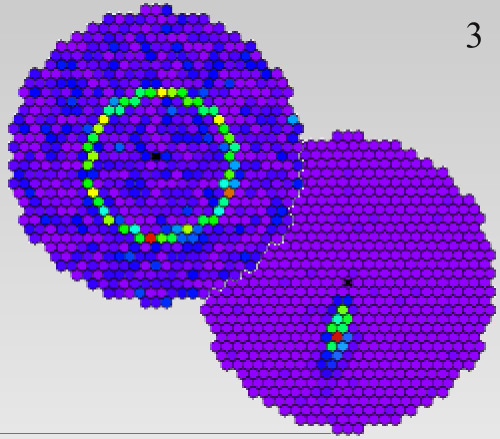
Status of FACT – The **F**irst G-**A**PD **C**herenkov **T**elescope

Thomas Bretz
for the FACT Collaboration


TU Dortmund
Uni Würzburg
ETH Zürich
EPF Lausanne
Uni Geneve (ISDC)
DWARF prototype
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2010 Tele Atlas
US Dept of State Geographer
© 2010 Europa Technologies



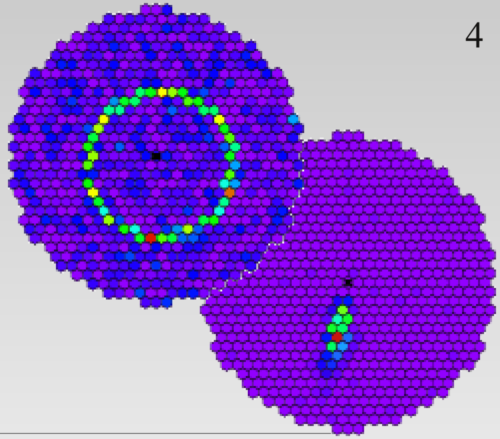
The Telescope



<u>The idea</u>

- Affordable monitoring telescope
  - observing only a few target objects (Mkn421, Mkn501, ...)
  - with large duty cycles
- Small-aperture as a prototype to a world-wide 24/7 monitoring network
  - Refurbish one of the former HEGRA telescopes
  - switched off since ~2002
  - CT3 still at La Palma

The Telescope



Upgrade:

New drive system

- MAGIC type / installed

Refurbished mirrors

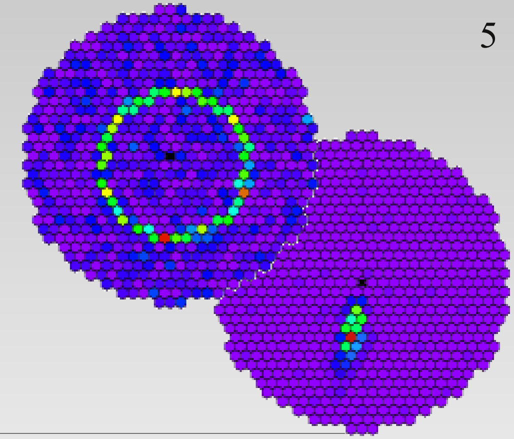
- hexagonal / larger area (9.5m²)
- better reflectivity
- Extension with plastic mirrors (in prep.)

New camera:

- First Cherenkov camera using G-APDs as photon detectors
- Integrated electronics

Artist view not long ago

The Telescope



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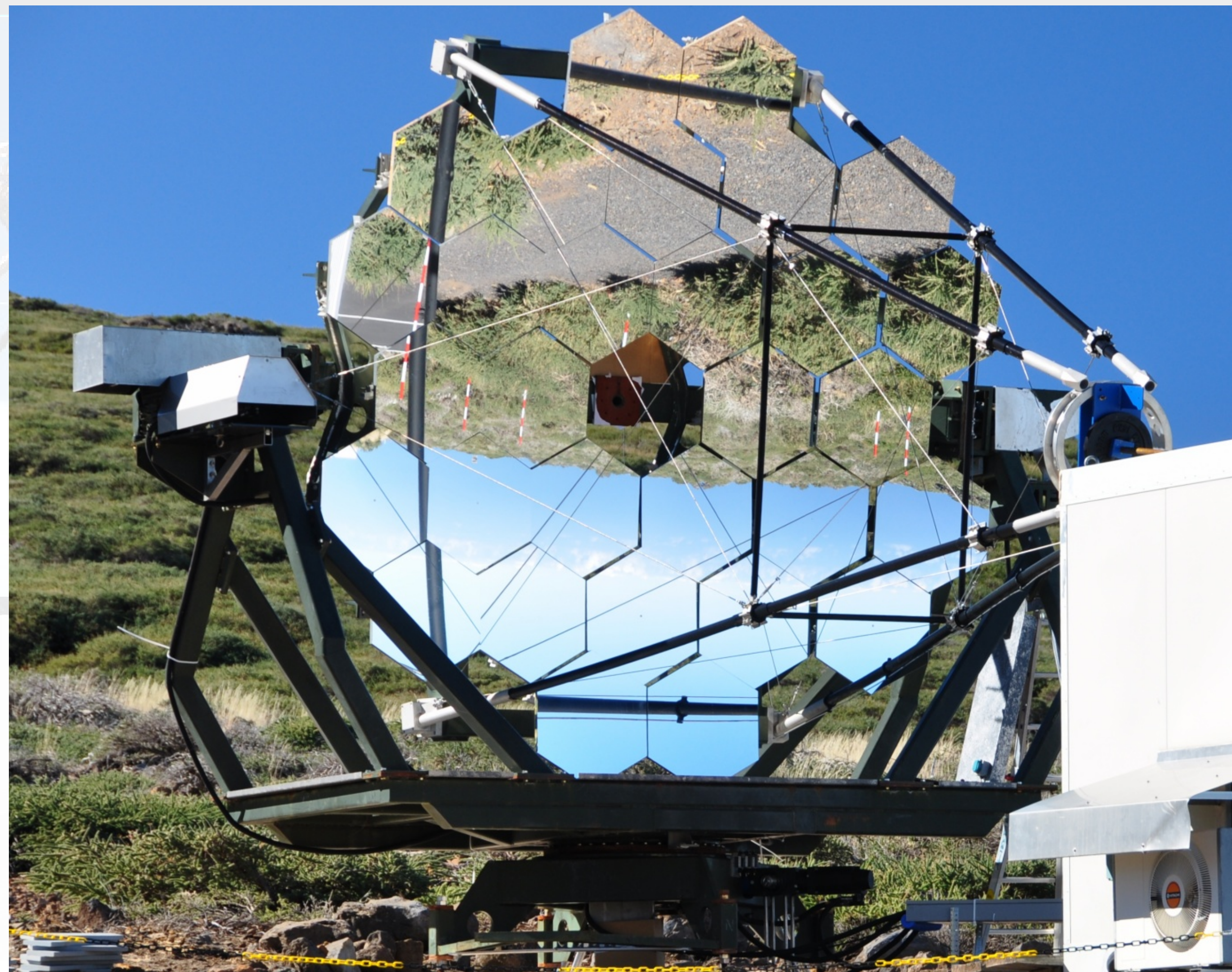
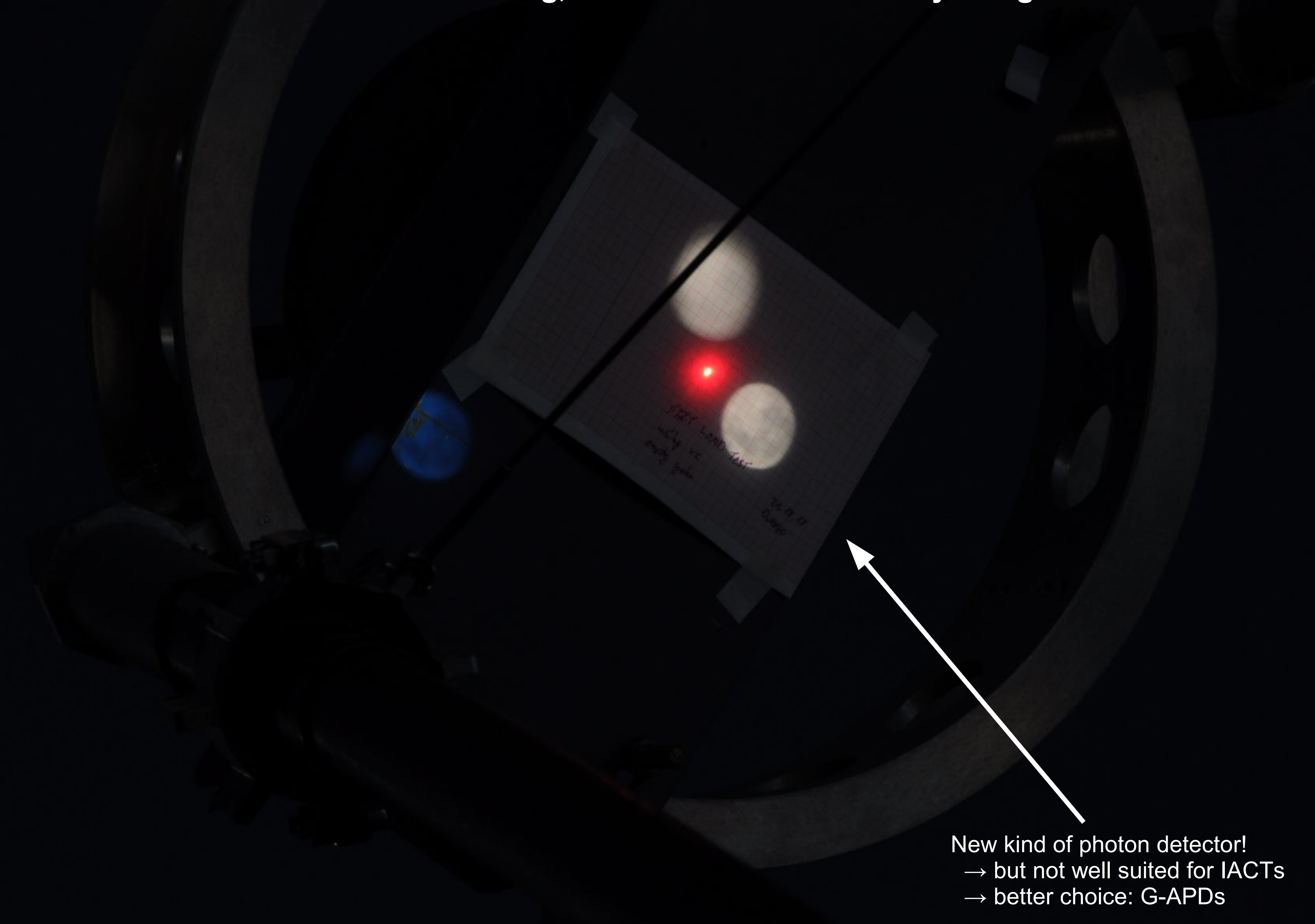
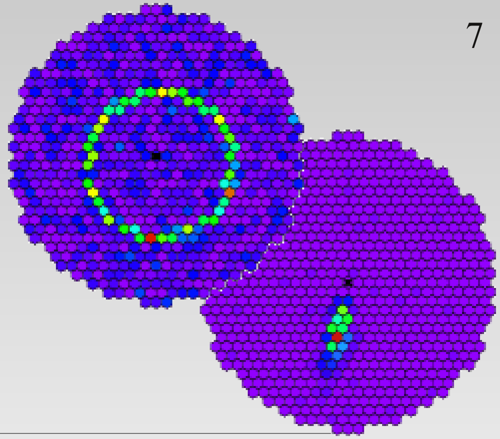


First Tracking, mirrors mounted but not yet aligned



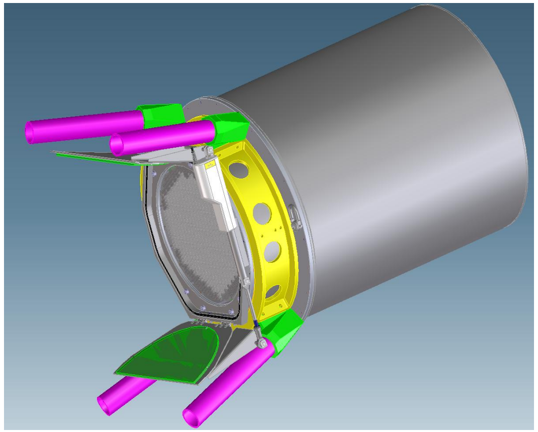
The Camera



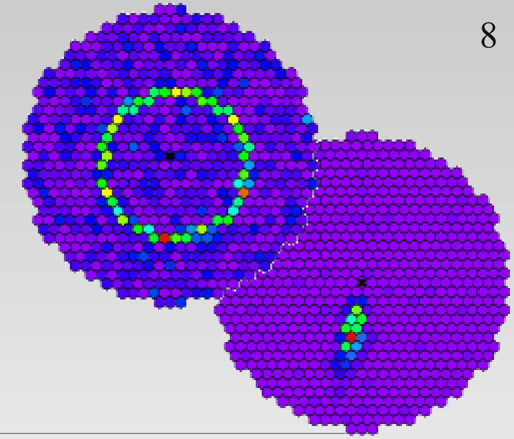
- First Cherenkov camera using G-APDs as photon detectors
- Integrated electronics

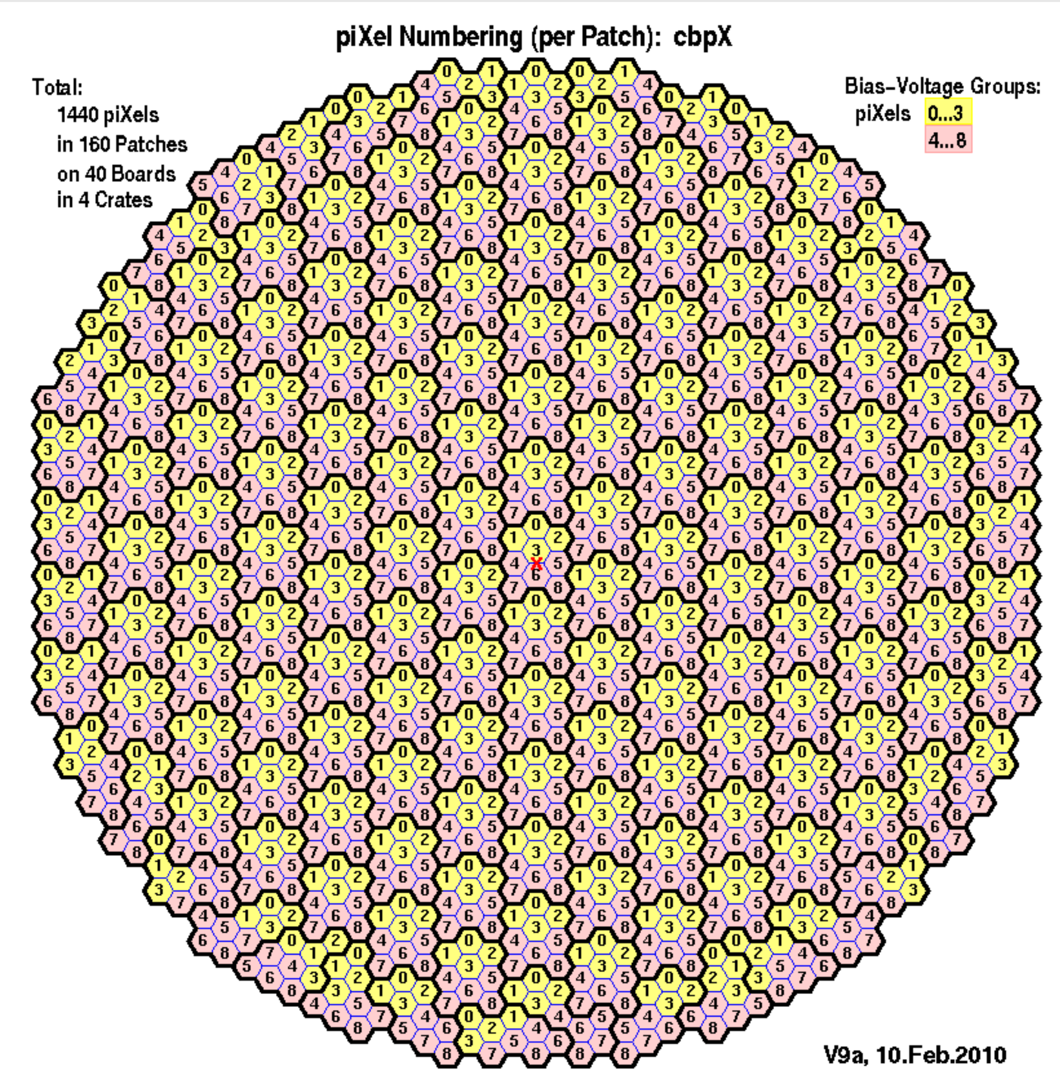
- 1440 pixels (~0.11°/pix)
- 4.5° field-of-view
- ~100kg

- DAQ: DRS4 (Ethernet readout)

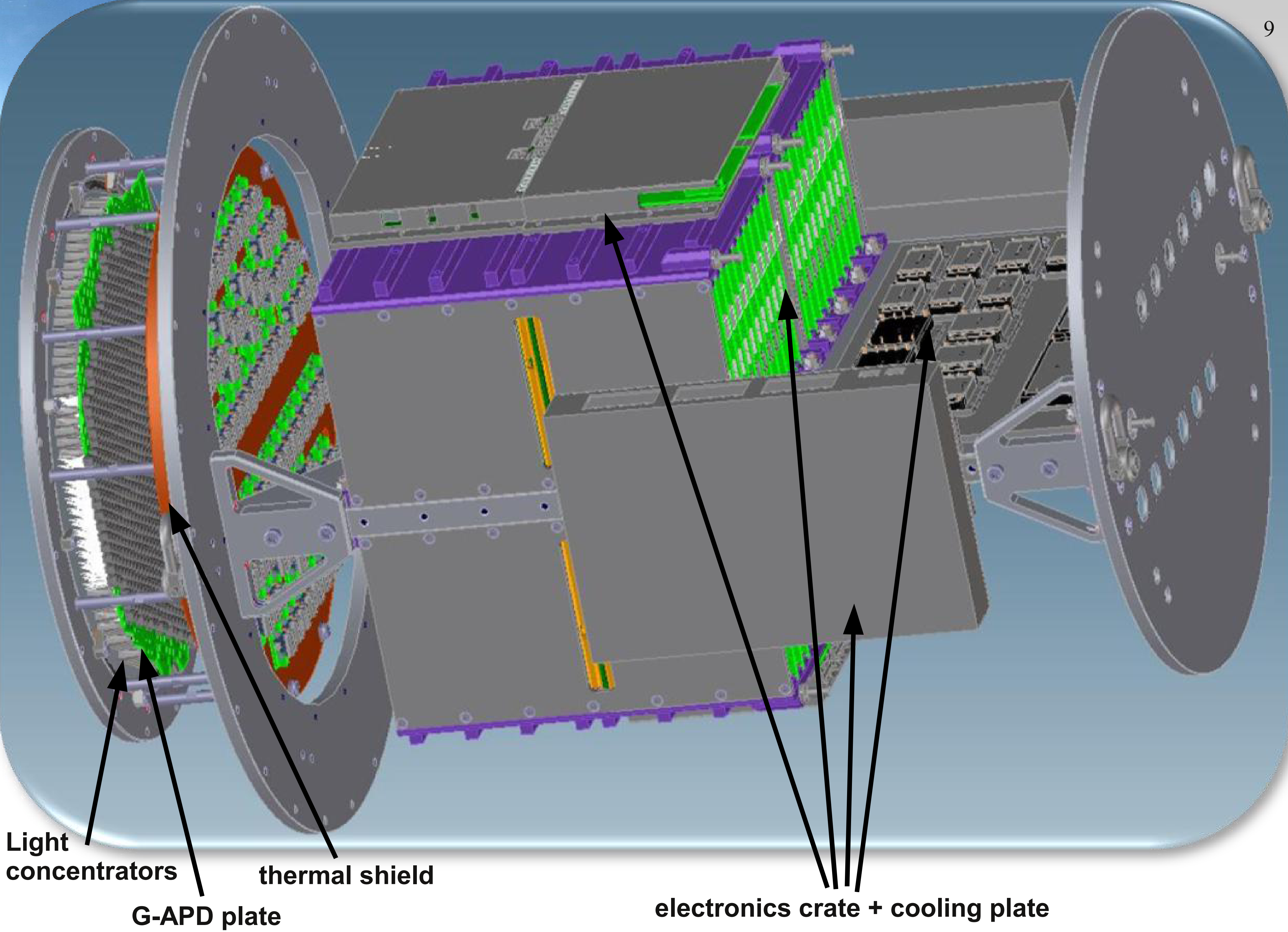


The Trigger

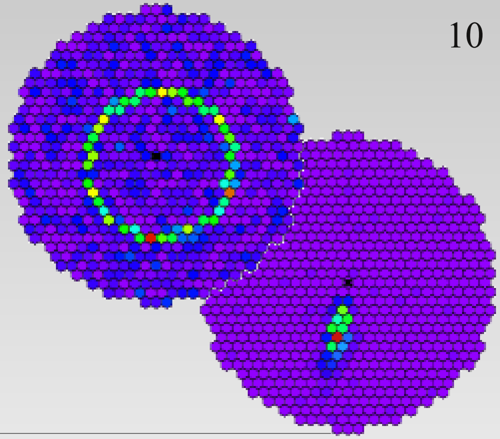




- First Cherenkov camera using G-APDs as photon detectors
- Integrated electronics
- 1440 pixels (~0.11°/pix)
- 4.5° field-of-view
- ~100kg
- DAQ: DRS4 (Ethernet readout)
- Sum-trigger with non-overlapping patches of nine pixels (close to *ideal*)
- Software trigger possible


Light
concentrators
thermal shield
G-APD plate
electronics crate + cooling plate

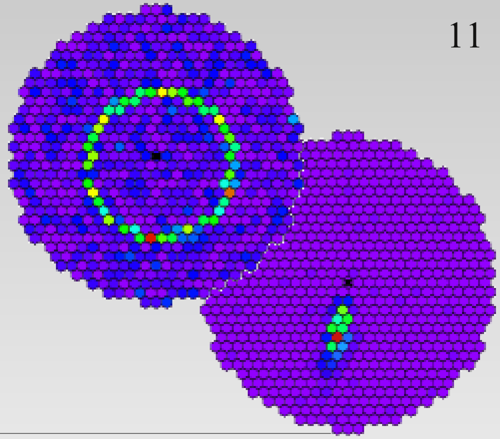
Why G-APDs?
advantages



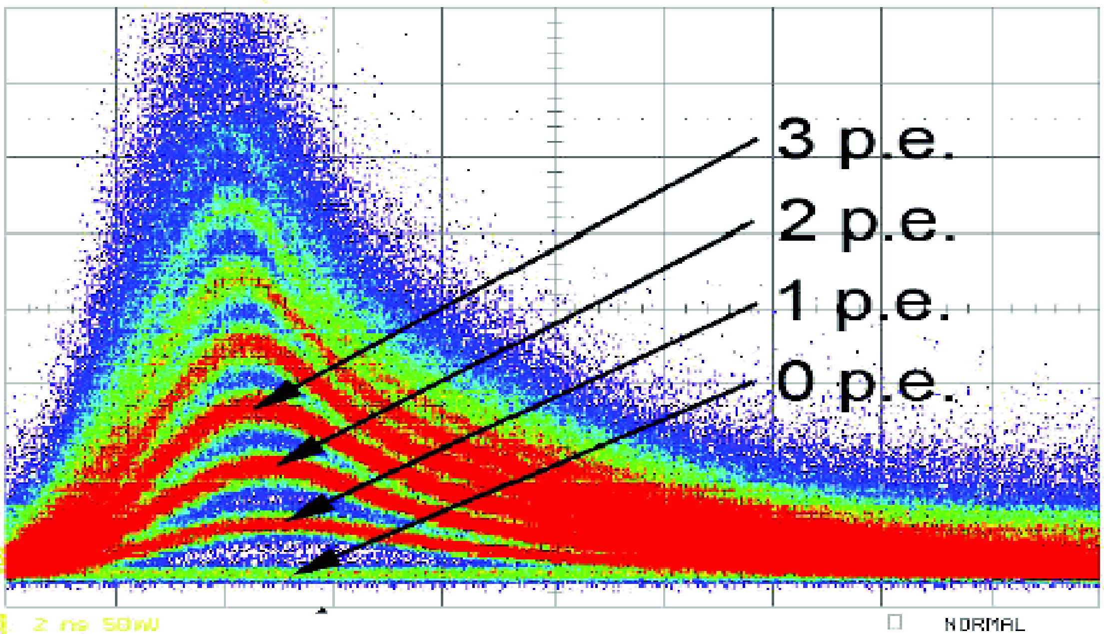
Most obvious advantages:

- Higher PDE (currently 30%-40%, but 70% possible)
- Single pe resolution (see next slide)
- Much lower bias voltage in the order of 70V
- More robust (can survive even exposure to direct sun-light)
- Easier to handle (less fragile)

Why G-APDs? singe pe counting

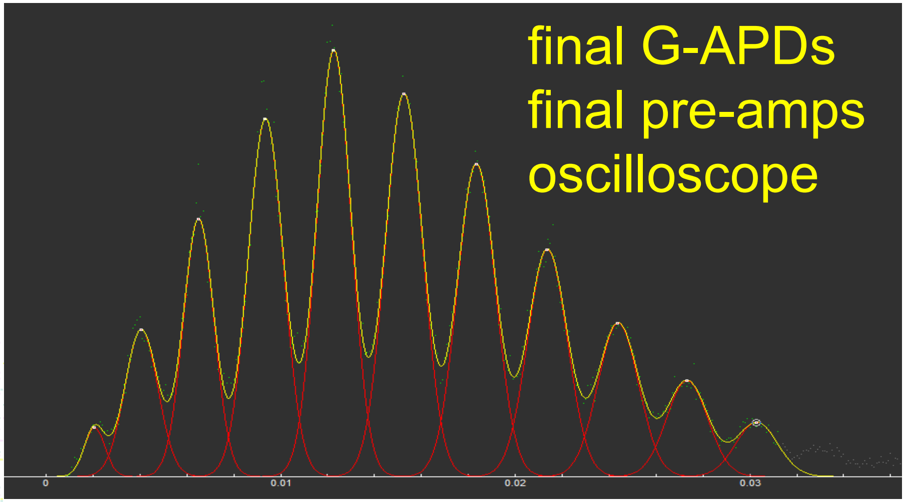


- G-APDs have very good single pe resolution
- Slower rise time than the best PMTs but very constant signals

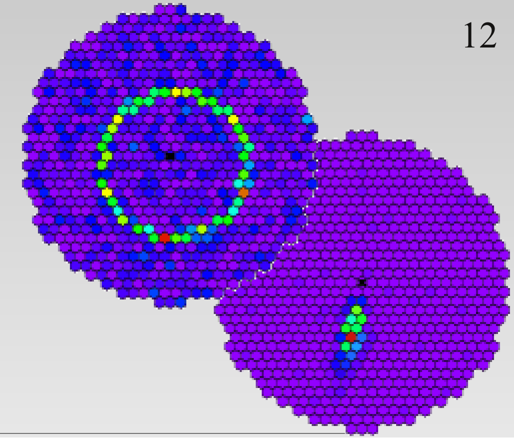


LED spectr., 2 ns horiz., 50 mV vert. spacing

Single pe separation using our electronics



Why G-APDs?
saturation

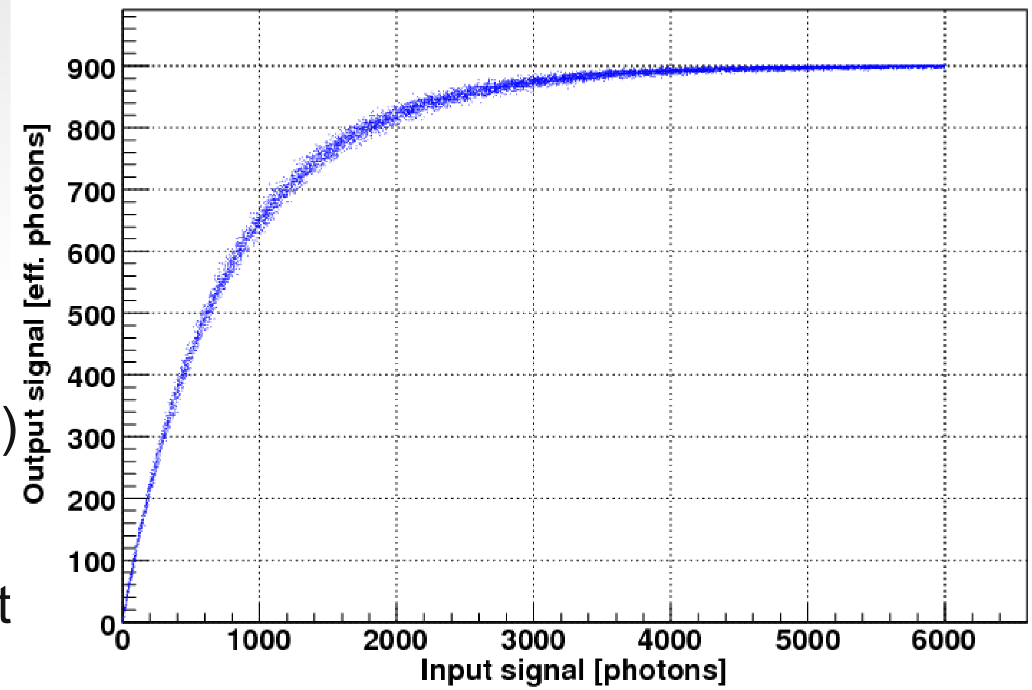


Possible disadvantages:

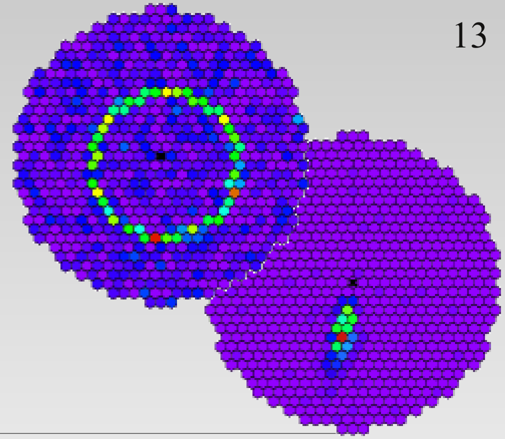
- **Saturation**
  - ➔ number of cells >> $R_{nsb} \cdot T_{recovery}$
  - ➔ More cells means more dead area (limits the PDE)

- Temperature dependance (~5% / degree)
  - ➔ temperature **or** gain stabilization via feedback system (stable cal. signal, keep signal height constant by adapting voltage)

- Sensitive >> 700nm
  - ➔ Increased NSB rate (but NSB rate vs threshold steep enough that energy threshold doesn't change significantly)



Why G-APDs? temperature dependance



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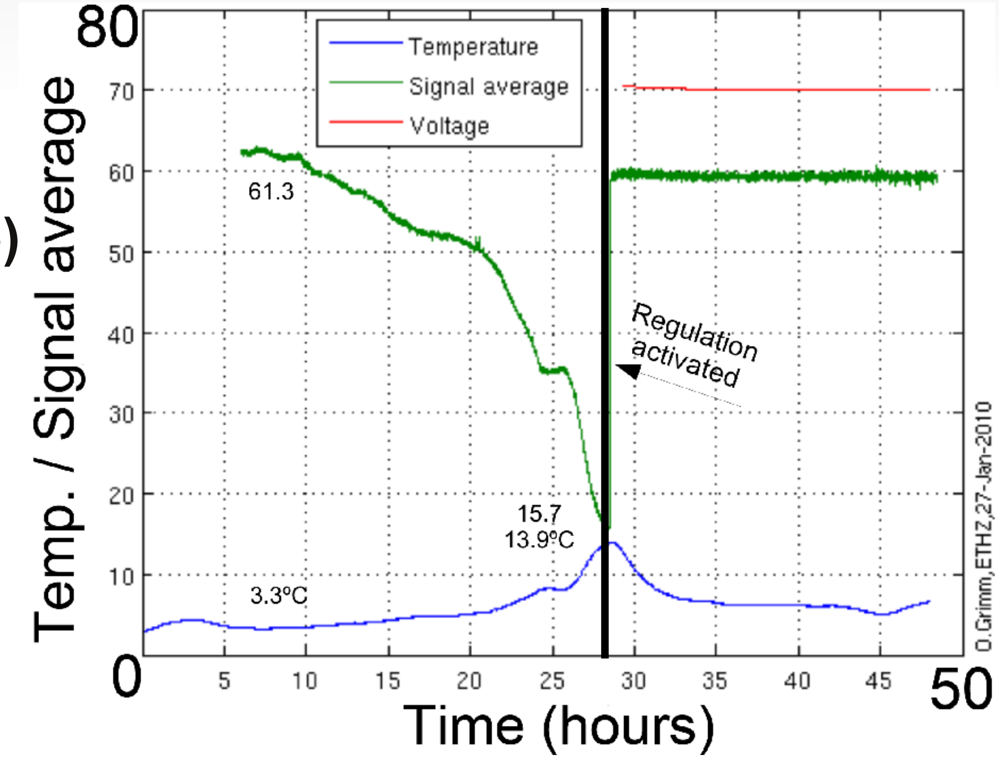
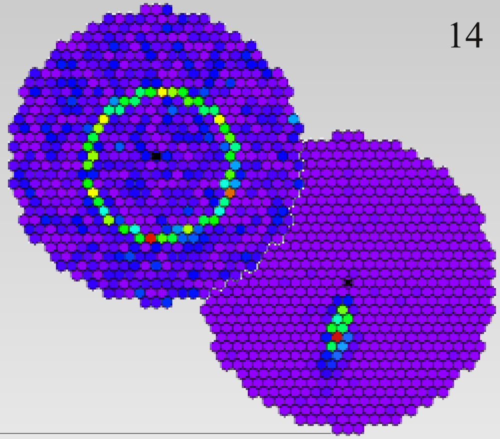
Regulation activated



Why G-APDs?



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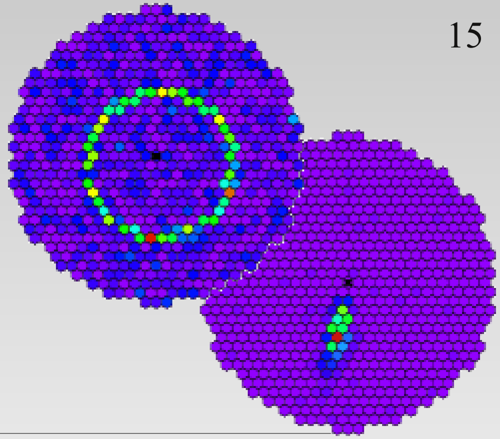
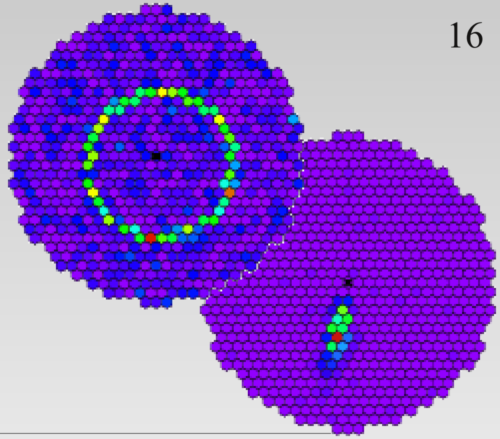
Why G-APDs?
dark counts



<u>Possible disadvantages:</u>

- Dark counts (in our case O(5MHz) per G-APD)
  → **but NSB rate O(50MHz)**
- Afterpulses (gain-dep. prob. 5%-20%)
- Crosstalk (gain-deb. prob. 5%-20%)
- Small collection area
  (3 x 3mm, maybe soon 5 x 5mm)

Why G-APDs?
afterpulses



Possible disadvantages:

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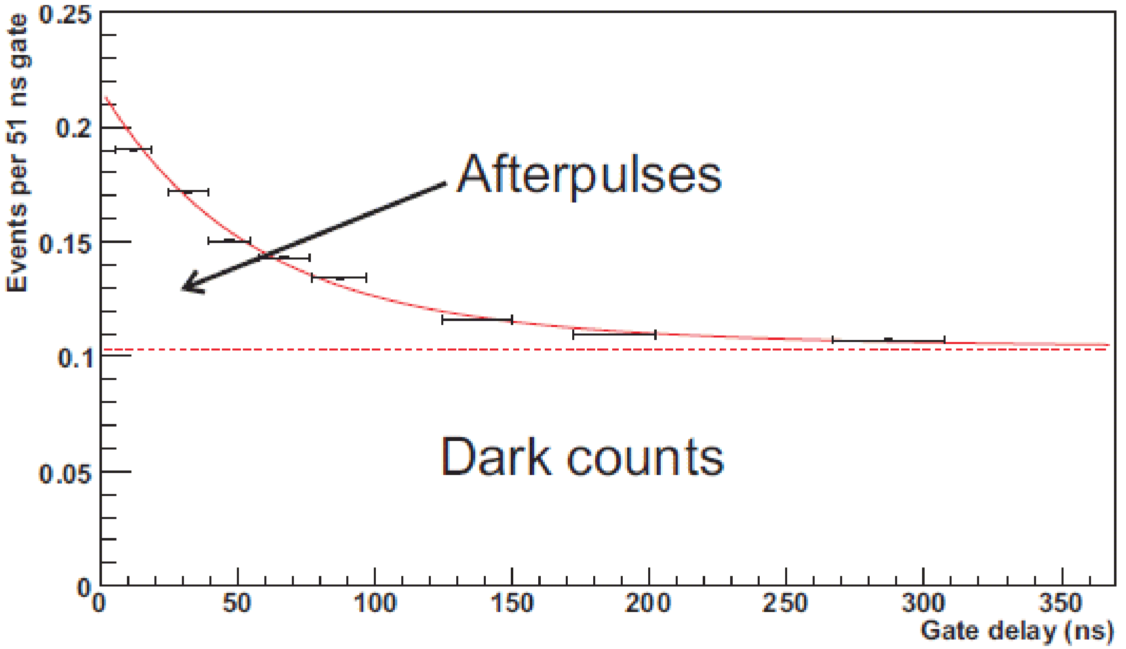
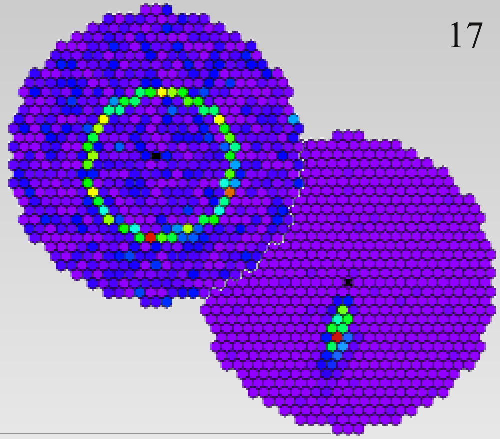
  (3 x 3mm, maybe soon 5 x 5mm)

Exponentially decr. prob. after breakdown



Why G-APDs?
crosstalk



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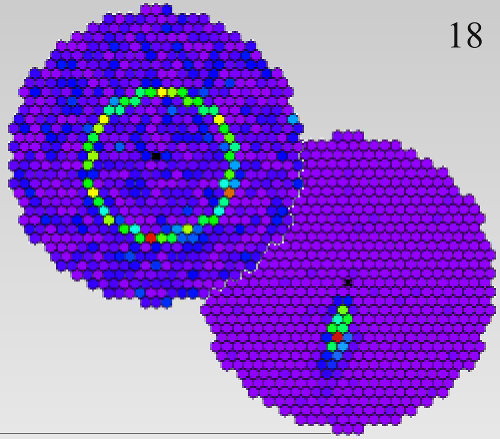
- Crosstalk (gain-deb. prob. 5%-20%)
  → **Important for single pe counting, but not for CTs**
  → **just increases the average signal height and slightly its fluctuations**
- Small collection area
  (3 x 3mm, maybe soon 5 x 5mm)

Why G-APDs? collection area



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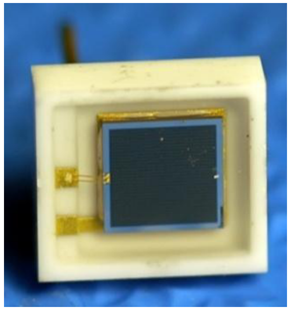
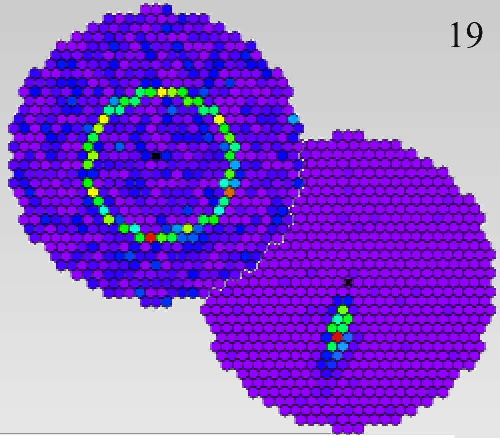
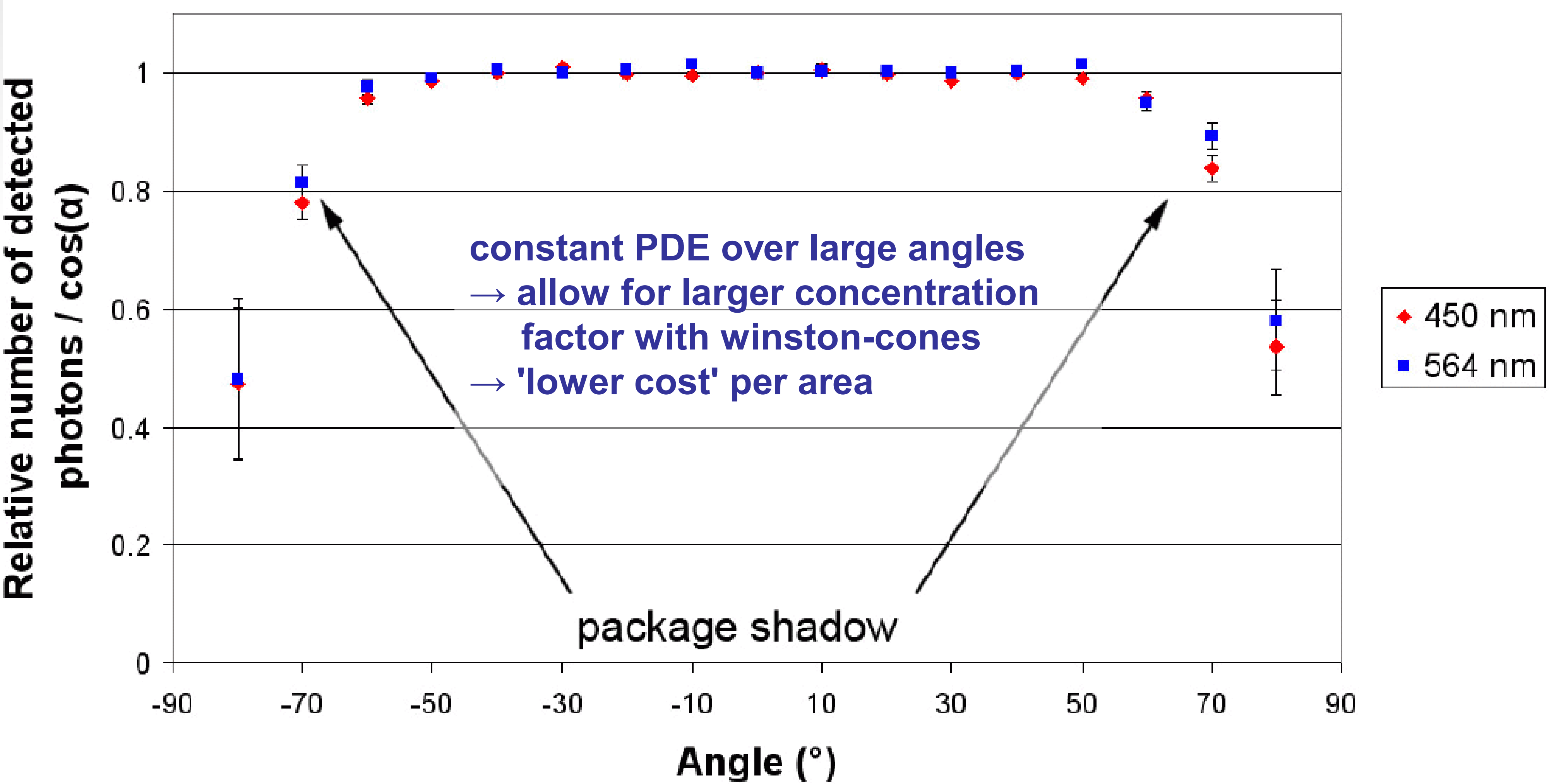
  → **Important for single pe counting, but not for Cts**
  → **just increases the average signal height and slightly its fluctuations**
- Small collection area
  (3 x 3mm, maybe soon 5 x 5mm)
  → **But almost 2·Pi angular acceptance**

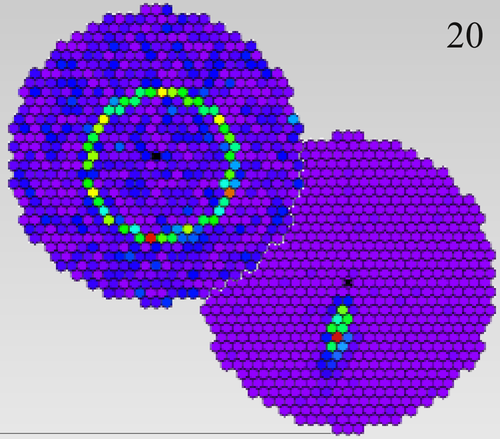


G-APDs angular acceptance



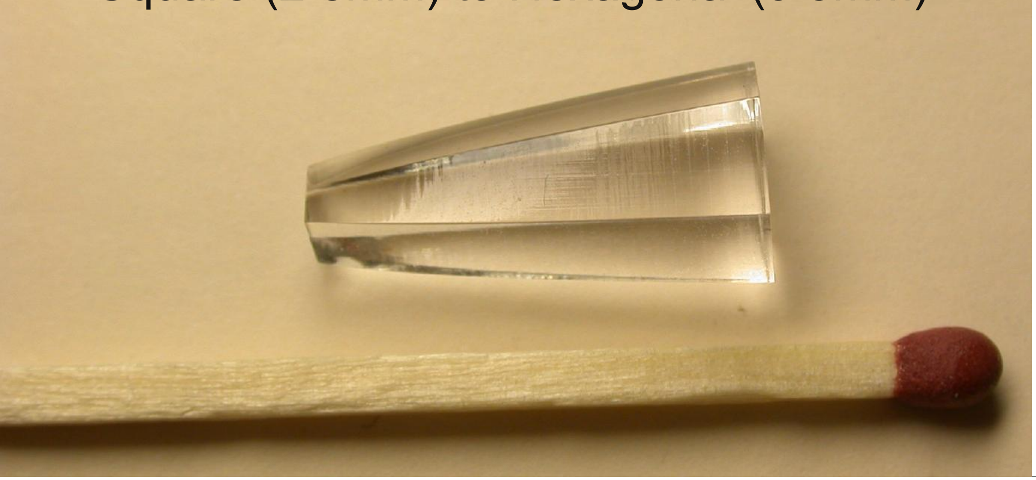


Solid cones - advantages



- The large angular acceptance allows already for a higher compression ratio than for PMTs
- In addition: G-APD properties (small size → low weight) allow the use of solid cones

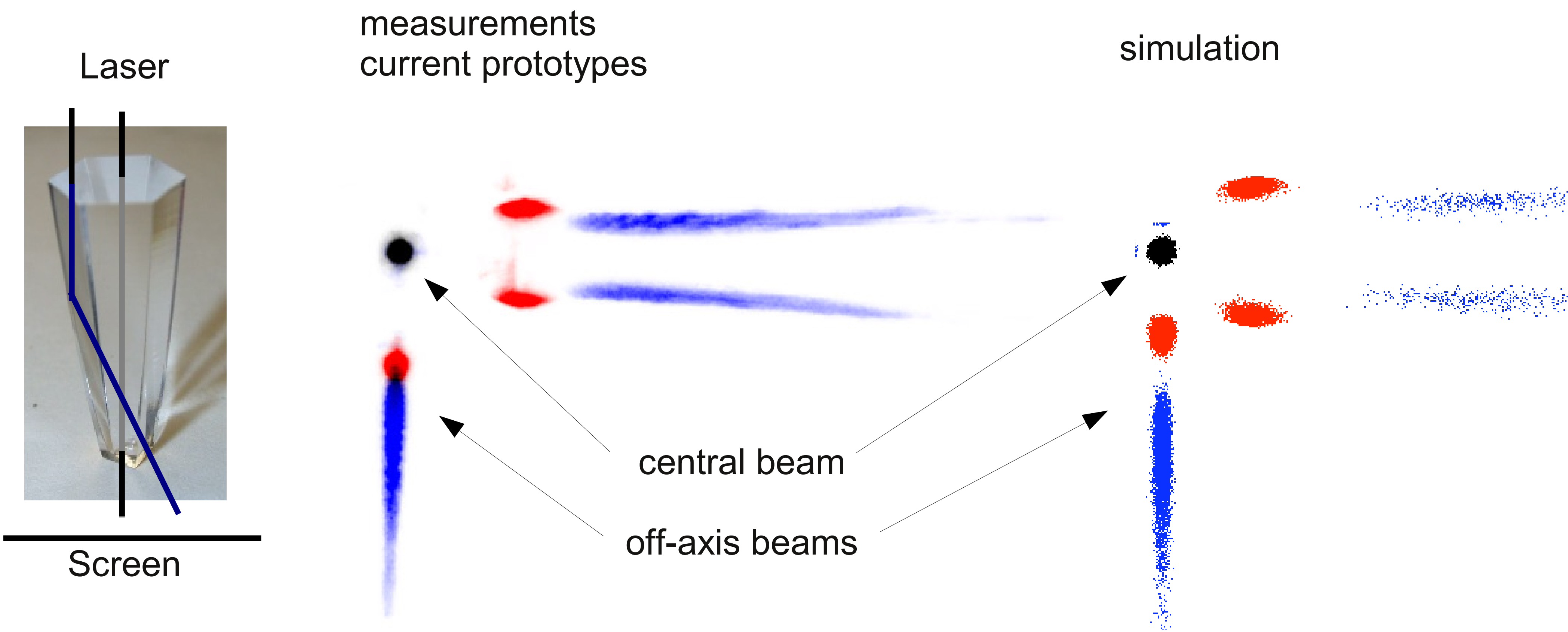
Square (2.8mm) to Hexagonal (9.5mm)



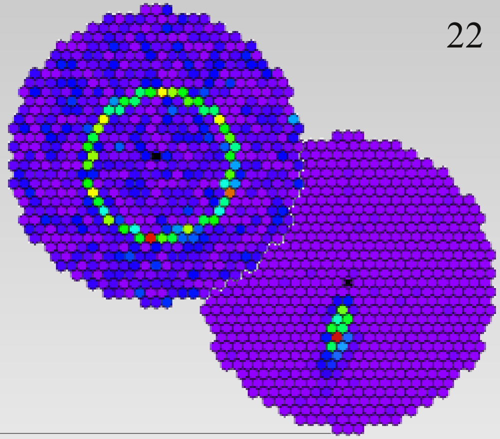
<u>Solid cones</u>

- Higher compression ratio, O(10) (due to Fresnel-reflection)
- Higher reflectivity (total reflection)
- cheaper and easier to produce (injection molding)
- rather complicated shapes possible

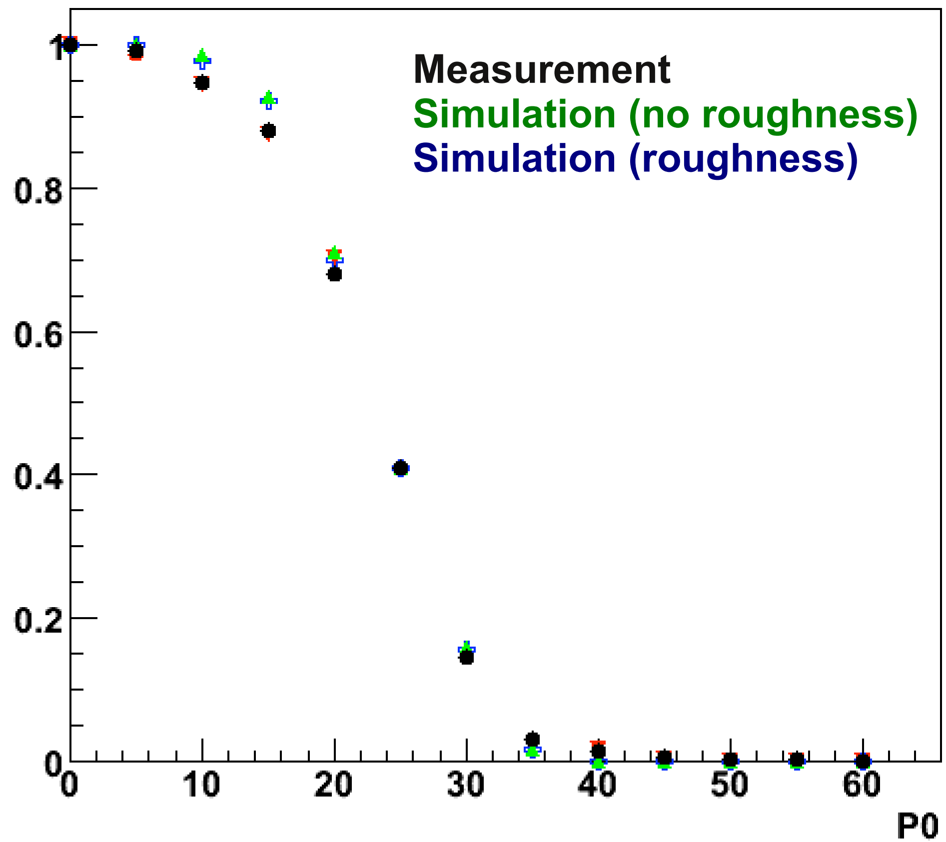
Image of laser beam parallel to axis



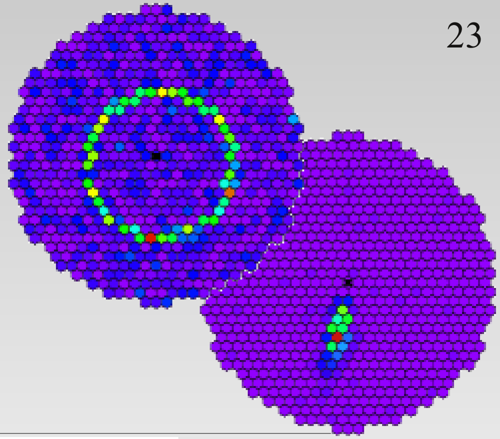
Solid cones angular acceptance

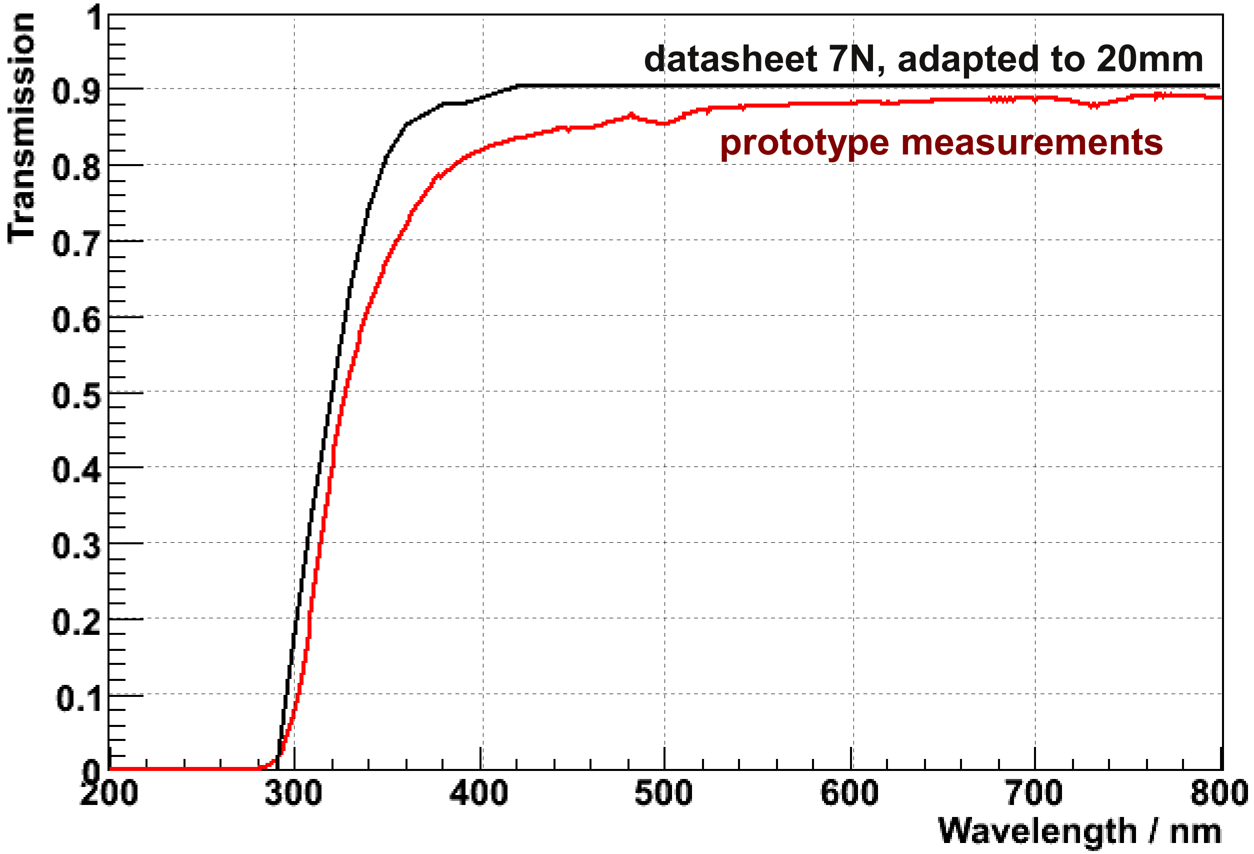


Angular acceptance of measurement fits the simulation quite well



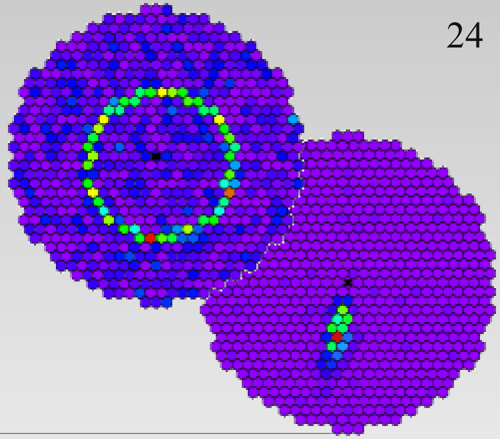
Solid cones - transmission

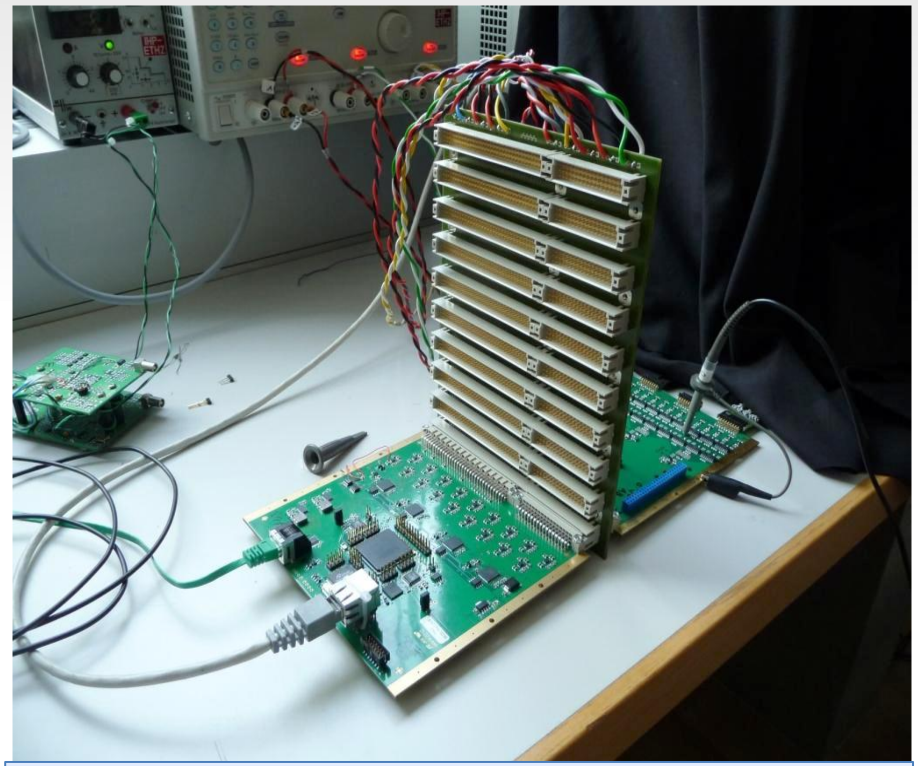




Light loss compared to data sheet (if folded with C-spectrum and G-APD acceptance) O(%)
Curves include <u>two</u> Fresnel-reflections (real transmission will be 4% higher)

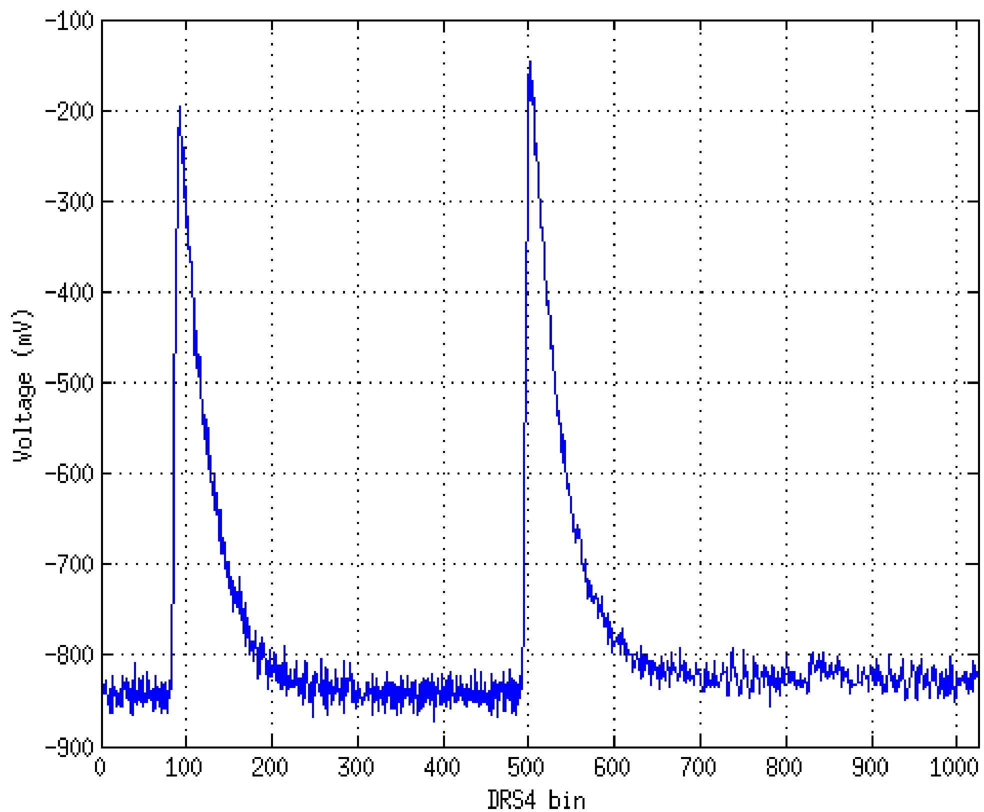
The Camera - prototypes



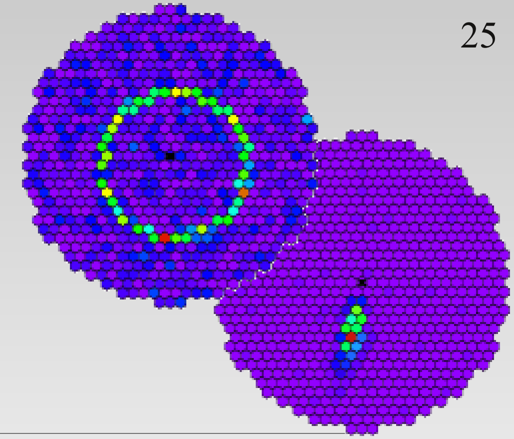


Pre-amplifier board, analog pipeline and digitization board (DRS4) connected via the mid plane, distributing power and slow control signals

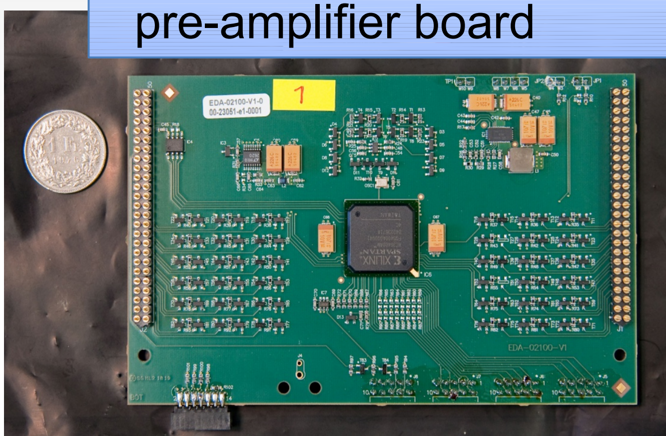
LED flashes registered by a G-APD connected to the FACT readout system



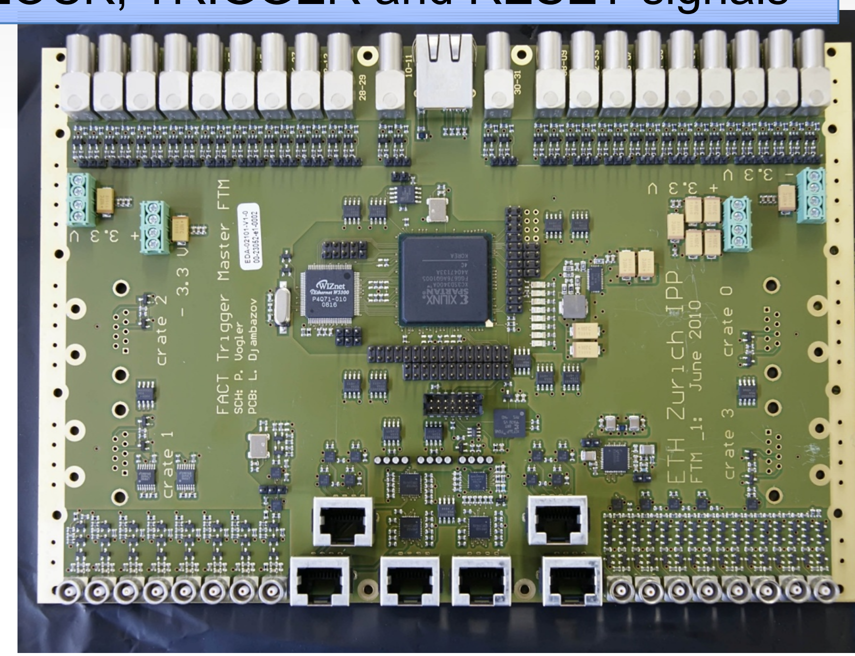
The Camera - prototypes



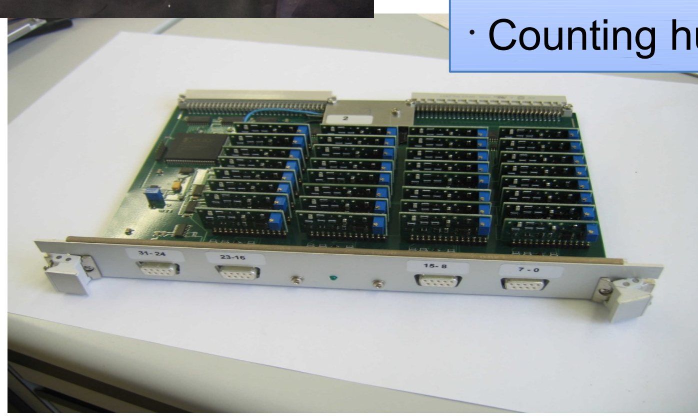
Trigger unit (FTU) – 40 pieces
- Discriminator, rate counting
- Mezzanine card on the pre-amplifier board



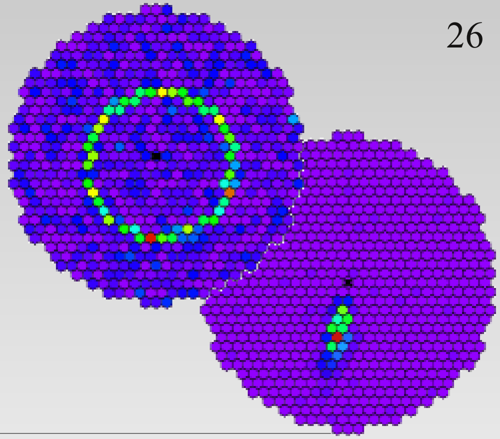
Trigger master (FTM) – 1 piece
- Provides trigger decision upon 40 FTU inputs
- Provides CLOCK, TRIGGER and RESET signals



32 channel GAPD bias card
- USB/PC controlled
- Counting hut



Conclusions



- **After two years of hard work, the FACT- telescope will become a reality soon**
  - Mirror and drive system installed
  - Prototypes of major components tested
  - Series production of most components started
  - Readout of a single channel tested (G-APD + pre-amp. + DAQ), gives very promising results
  - Series production of the pre-amplifier boards and readout boards in prep. after minor changes, will start in two weeks
  - Present prototypes for the cones show properties very close to our expectations, production will start soon, too

  ➔ **Full system build ready in the first half of 2011**

- Our experience: **G-APDs seem to be an extremely good alternative to PMTs in IACTs**
  Just a number: You need only ~10 G-APDs with solid cones to get a comparable sensitive area to a MAGIC PMT – 10 x 20€ ~ 200€

Thank you!

Camera: Prototype-electronic available, starting series production